Europe's Challenge: A Smart Power Market at the Centre of a Smart Grid

Project Overview

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Descriptors

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About CPI

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Executive Summary

The CPI Smart Power Market analysis project, in support of the EU RE-Shaping project, addresses the question of how to achieve an effective power market design that supports the EU's smart grid goals. The project includes this overview paper, three papers covering congestion management, wind integration, and quantification of the value of various market designs, as well as a Q&A document on the nodal pricing system.

Key findings

Congestion Management in European Power Networks
By 2020, European member states plan to connect an additional 200 GW of wind and solar power to the transmission system on top of the 110 GW connected before 2010. The new flow patterns (both nationally and internationally) resulting from this connection highlight three weaknesses of the current system for managing congestion:

- Inefficiencies within countries. Currently, gaming opportunities and inefficient dispatches occur, because the market does not properly communicate information on the value of generation at different locations.
- Inefficiencies between countries. Cross-border transmission is treated separately from domestic dispatches, leading to incomplete information on required demand and generation and increasing system risk.
- Inefficiencies in dynamic management. International transmission capacity is usually determined far ahead of real time, which constrains the ability of the EU power system to flexibly deliver power and ancillary services across Europe in response to short-term adjustments in generation and demand.

With these inefficiencies in mind, we assess current and proposed congestion management approaches according to five criteria. The congestion management approaches applied within and between European countries do not satisfy these criteria. In contrast nodal pricing, a power market design that has become standard across most of the liberalised markets in the US over recent years, addresses all the requirements.

Balancing and Intraday Market Design: Options for Wind Integration
Though wind is a highly unpredictable source of energy, wind forecast uncertainty decreases from 15% to 4% in the last 24 hours before actual generation, and the grid, demand, and most generation assets can be adjusted within this timeframe. We identify six criteria that a power market design needs to satisfy to make full use of the technical flexibility of the system and short-term wind-forecasts. Power markets should:

- Facilitate system-wide intraday adjustments to respond to improving wind forecasts;
- Allow for the joint provision and adjustment of energy and balancing services;
- Manage the joint provision of power across multiple hours;
- Capture benefits from international integration of the power system;
- Integrate demand side into intraday and balancing markets; and
- Effectively monitor market power.

None of the power market designs applied across European countries meets all six criteria. Only a regime based on nodal pricing can address these requirements, support wind-

integration at minimum system cost and allow for part-load operation of fossil power stations.

Renewable Electric Energy Integration: Quantifying the Value of Design of Markets for International Transmission Capacity
Using the ENTSO-E database and three large-scale models for the European power system, the performance of a nodal pricing system is compared to an optimised zonal pricing approach which is an extension of systems currently in place in the EU:

- The nodal pricing approach leads to an increase of up to 34% in international transfers between countries, depending on wind power penetration. This means that the existing network capacity can accommodate increasingly large volumes of intermittent energy sources.
- Annual savings on system marginal costs under a nodal pricing structure range from €0.8 - €2.0 billion depending on the penetration of wind power, representing an average of 1.1% - 3.6% of operational costs, which is in line with empirical values from the USA.
- Weighted marginal prices are cheaper under a nodal pricing regime in 60% to 75% of EU countries.

1 Introduction

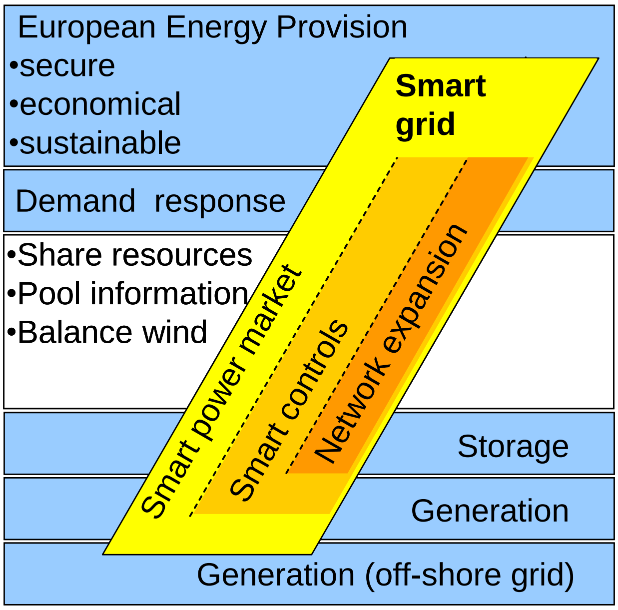
Power markets play a central role in the transition to a low carbon energy system. Not only do they facilitate power transactions, but they also impact the efficiency of electricity generation and transmission, can facilitate the growth of renewable energy, and can create incentives for building and investing in the right assets at the right time and place. In Europe, power markets have developed in response to a power system that evolved slowly over many decades. Now, with significant changes required of the European power system - including increased renewable supply, the retirement of many older conventional plants, transmission capacity expansion and the possible move to a smart grid, the current power market threatens to impede, rather than aid, system development. Action is required by European policymakers and power system operators to overcome the inertia inherent in the current set of power market designs.

"Smart power markets" are essential to smart grids

Smart grids will be the backbone of a de-carbonized power system. They will allow for increased connection of on-shore renewables (in particular wind and solar) while maintaining availability for conventional power generation and power system adequacy.

They will provide a seamless interface with the grid for off-shore wind; co-ordination with power storage technologies; increased sharing of information to facilitate use of short-term wind forecasts, and international pooling of reserves and balancing of wind output. Finally, they will provide appropriate incentives for, and co-ordination of, demand response (including smart metering).

Figure 1: The role of smart grids in the centre of a low-carbon power system.



The enablers of smart grids include smart control technologies, network expansion and "smart power markets":

- Smart controls use enhanced control technologies for generation (including the provision of ancillary services from renewable technologies), network optimization (such as Flexible

AC Transmission Systems/FACTS devices which optimize transmission and distribution), and demand (such as smart meters).
- The location of renewable resources does not often coincide with the location of conventional power generation assets (e.g. off-shore wind). Hence some grid expansion and enforcement is necessary to accommodate large shares of renewables in the system. Power markets can help to minimise grid expansion needs, and the resulting locational prices provide information and evidence to support planning and investment decisions for grid expansion.
- While smart control technologies and network expansion to include renewables are important elements in a smart grid, there is a third, a 'smart power market', that connects the first two elements. These markets would allow for a flexible operation of the power system, use of all information for system optimization (including frequent updated snapshots of the whole network and short-term wind forecasts), and system-wide co-ordination to make effective use of the network. These 'smart power markets' complete the puzzle for a smart grid.

We focus on the structure and characteristics of the third element, the "smart power market." This report summarises the more detailed analysis of the papers (available at: www.climatepolicyinitiative.org):

- *Congestion Management in European Power Networks, 2010*:
  with B. Hobbs, D. Newbery (Electricity Policy Research Group, University of Cambridge).
- *Balancing and Intraday Market Design: Options for Wind Integration, 2010*:
  with F. Borggrefe (University of Cologne).
- *Renewable Electric Energy Integration: Quantifying the Value of Design of Markets for International Transmission Capacity, 2011*:
  with J. Barquin (Universidad Pontificia Comillas), J. Bialek (University of Durham), R. Boyd (CPI Berlin), C. Dent (University of Durham), F. Echavarren (Universidad Pontificia Comillas), T. Grau (CPI Berlin/DIW Berlin), C. von Hirschhausen (TU-Berlin), B. Hobbs (Johns Hopkins University), F. Kunz (TU Dresden), C. Nabe (Ecofys), G. Papaefthymiou (Ecofys), C. Weber (University Duisburg-Essen), H. Weigt (TU-Dresden).
- *Frequently asked questions on the international experience with nodal pricing implementation.*

The report is structured as follows:
1. Introduction;
2. The key requirements for future power market development;
3. Today's European power market and options for power market changes or redesign;
4. Advantages and disadvantages of these options;
5. Paths for transition to a smart power market; and
6. The positioning and incentives for key players in the transition to a new power market.

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2 The key requirements for future power market design

In the European power system, transactions are executed by national transmission system operators (TSOs) with very limited international co-ordination, using protocols that were designed for the coal age of power generation, which results in inefficiencies. European policymakers and power system operators could improve system efficiency and promote carbon savings through a transition to a market that addresses three key issues challenging the current system: the institutional issue of information sharing, the physical constraints of the transmission system, and the ability to incorporate short-lead generation sources. A smart power market will need to accomplish:

i. **System-wide information-sharing to maximize the potential resources available for use.**

In the European power system, national system operators share information about the state of the system on a limited and infrequent basis. Because of this, in order to ensure that lines are not booked beyond their capacity, operators constrain the use of transmission lines arbitrarily and schedule additional reserves. Despite this conservative utilization of the network, local and regional black-outs have occurred in recent years as a result of missing information exchange and co-ordination. An optimized, effective dispatch system that is reliable is possible only with full system visibility.

ii. **Incorporation of transmission capacity into pricing.**

Transmission lines need to carry not just electricity flow that is transacted between countries but also electricity flow within countries. In Europe, national Transmission System Operators (TSOs), who must provide for domestic transmission, can control only the amount of capacity available for international flows. To avoid penalty costs for changing schedules after they have been set, operators tend to be conservative in their estimates of capacity available for international flows, and so end up reducing international transactions based on conservative and often inaccurate estimates of available capacity. An effective power market will need to incorporate these transmission constraints.

iii. **Efficient incorporation of intermittent energy sources for which only short-term forecasts are accurate.**

Intermittent energy sources such as wind may have the lowest variable costs of production, but are more unpredictable than conventional power sources. To incorporate these intermittent sources, a power market needs to be flexible enough to accommodate short-term forecasts and quick turn transactions. This is valuable particularly with respect to wind energy, where wind forecast uncertainty decreases from 15% to 4% in the last 24 hours before actual generation (RMS in Germany). A power market that accommodates short-term forecasts also encourages efficiency from conventional energy sources avoiding the need for additional balancing and reserve capacity[1]. As an example, smart auctions in Spain caused conventional generation assets to start, stop and change their output based on these more accurate forecasts.

[1] See presentation by Ignacio de la Fuente, Red Eléctrica de España, "Adjustment of Unit Dispatch in Spain". www.climatepolicyinitiative.org

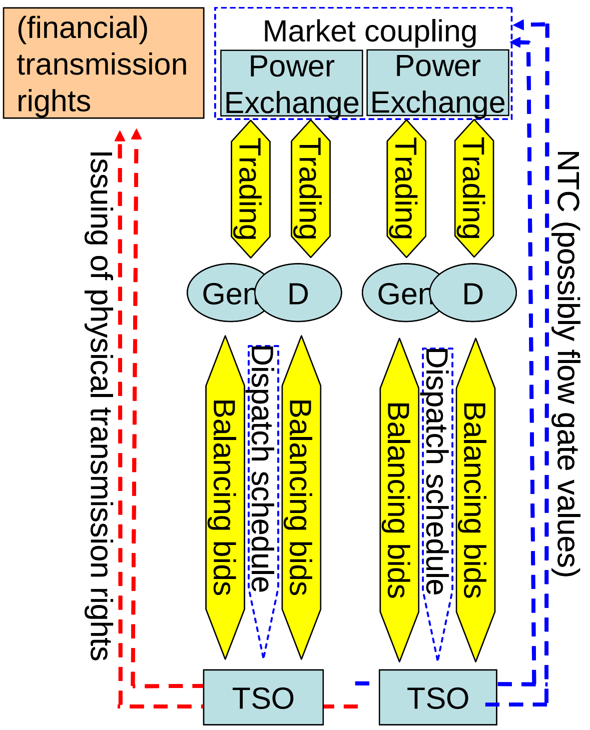
3 European power market and options for power market changes or redesign

3.1 Today's power market

Figure 2 describes the current structure of European power markets. Energy is traded bilaterally and on national power exchanges in yearly, monthly, and day-ahead markets. For international transactions, regional or national transmission system operators (TSOs) or electricity suppliers acquire transmission rights through auctions, so as to hedge the financial risk they would face from different market prices in both regions.

At gate closure, one to three hours before the final dispatch decisions are made, participants announce to the system operator their energy needs as well as production plans (including how much and where they will produce). For international transactions, market participants must submit the corresponding physical transmission rights, acquired in transmission rights auctions.

Figure 2: Current structure of European power markets. Key: "Gen" – Generator. "D "– Demand.



TSOs then check whether the submitted dispatch schedule is compatible with transmission capacity of the system, and will use balancing bids offered by market participants to address possible constraints. Balancing bids and balancing services contracted on longer-term arrangements are also used to adjust imbalances where generation or demand deviates from the nominated dispatch schedule.

As discussed above, the current EU market is inefficient because it does not facilitate the effective dispatch of the electrical system, and does not address intermittent energy sources. The current potential fixes under discussion are: 1) market coupling; 2) the incorporation of loop flows; 3) an integrated power market design.

3.2 Market coupling

Market coupling is a method for integrating electricity markets in different areas. With market coupling, the daily cross-border transmission capacity between the various areas is not explicitly auctioned among the market parties, but is implicitly made available via energy transactions on the power exchanges on either side of the border (hence the term implicit auction). It means that the buyers and sellers on a power exchange benefit automatically from cross-border exchanges without the need to explicitly acquire the corresponding transmission capacity[2].

Market coupling enables transactions with short time-frames and low liquidity. France, Belgium, and the Netherlands, as well as the Scandinavian countries, have coupled their day-ahead markets, and further expansions to integrate Germany and couple both regions are in progress. In participating markets, power exchanges are informed by the TSO about the available transmission capacity between countries. If market clearing prices of adjacent power exchanges differ and transmission capacity remains available, then the clearing mechanism makes use of this capacity to automatically accomplish transactions. Such a system is an improvement upon the previous system, because it creates a somewhat more flexible, nimble power market, though it still relies on TSO estimates, rather than real transmission capacity.

3.3 Incorporation of international loop-flows

Traditionally, TSOs have only declared the transmission capacity that can be made available for transfers between individual adjacent countries (net transfer capability), for instance from Germany to the Netherlands. Because parts of exports from Germany to France also have to go through lines in the Netherlands and Belgium (called parallel or loop-flows), the magnitude of flows through specific transmission lines depends on the precise generation location, which is not visible to system operators day-ahead or intraday. Therefore, when setting transmission capacity for bilateral transactions, TSOs must be conservative, so as to accommodate potential use of transmission capacity for exports, e.g., from Germany to the Netherlands, and from Germany to France.

An improvement that has been in discussion for some time among European regulators and transmission operators is to incorporate international loop-flows explicitly. Rather than only declaring the available transmission capacity between individual adjacent countries, TSOs could declare, for example, how much transmission capacity is available for critical network paths. In our example, if transmission capacity were not used for exports from Germany to France, more transmission capacity would be made available for exports from Germany to the Netherlands. Also under discussion and testing are international loop-flows both for the allocation of long-term transmission rights and for the joint market clearing among power exchanges that engage in market coupling[3].

3.4 Integrated power markets with locational marginal pricing (LMP)

Another approach to improving the current setup is to establish an integrated power market with locational marginal pricing (LMP – also known as nodal pricing), where there is one price that is then adjusted for transmission and generation constraints. This system, which was initiated in three states in the United States in 1998, has since expanded to cover 13 states and Washington D.C., totalling

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[2] Definition of market coupling from BELPLEX website.
[3] See e.g. http://www.ecn.nl/docs/library/report/2004/rx04088.pdf

165 GW of generation capacity, and has been replicated in other regions, including NY-ISO, ISO-New England, ERCOT (Texas) and California.

In the US, these integrated power markets are managed by Independent System Operators (ISOs) who obtain full information about the state of the network every five minutes from network operators, including information about maintenance and line failures. The six ISOs in the country manage the physical high-voltage transmission system in their respective regions and trade energy for day-ahead and intraday markets. ISOs have a regional monopoly position in terms of physical system management, which is derived from the natural monopoly inherent in power networks. Many traders and independent exchanges participate in the integrated markets, however, and submit power schedules to an ISO's various markets.

Figure 3: Structure of US power markets with locational marginal (nodal) pricing.

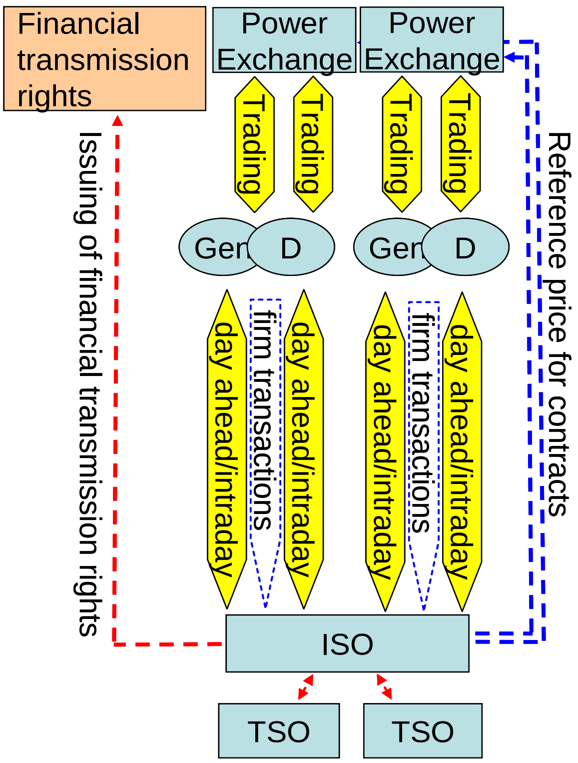

Figure 3 describes the US integrated power markets, which contrast with the European situation shown in Figure 2. In these integrated power markets:

- Long-term trading continues to reside on power exchanges and in bilateral arrangements.
- Financial transmission rights to hedge locational price differences are initially allocated for free with additional capacity auctioned to market participants.
- Generators can submit schedules with firm transactions in the day-ahead market and are charged for/receive the locational marginal transmission rate (price differences between location of generation and load). This difference can be hedged with financial transmission rights.
- Generators and the demand side can submit bids in the day-ahead and intraday markets to adjust their production/consumption relative to their initial trading position where this is profitable.
- Information about generator constraints is taken into account. As generators can inform the ISO about start-up costs, ramp-times and part-load constraints, the ISO can ensure that the resulting dispatch schedule is technically and economically viable for a generator.

In contrast, the current system does not link or provide visibility across time markets and does not fully consider generator constraints. For instance, without this information, a generator may be asked to operate assets for the noon to 1:00 pm market, shut down in the 1:00 -2:00 pm market, and start up again for the 2:00 - 3:00 pm market. In an integrated power market with an ISO, the ISO will have visibility across time markets and thus ensure that decisions are operationally viable and efficient.

- TSOs retain responsibility for their grid, transformer station, maintenance, and communication with all assets connected to the grid. They must co-ordinate with the ISO when lines are taken out of service (as this can create risks for neighbouring TSOs) and respond to requests from the ISO for system reconfigurations that are necessary to prevent system failures.

4 Shortcomings of market coupling and the incorporation of international loop flows; advantages of the integrated power market

Market coupling and the incorporation of international loop flows go partway in solving the problems of the current market structure: market coupling allows for quicker transactions, and incorporating international loop flows solves one piece of the transmission capacity planning problem, but both retain two fundamental shortcomings: they do not address congestion within zones, and they do not facilitate the effective system-wide, intraday redispatch that is important in wind energy production.

With the implementation of market coupling and the incorporation of international loop flows, countries are still treated as single price zones, which, in addition to being inflexible toward annual price setting, does not take into account internal transmission constraints due to international transfers (the exception is Scandinavia's Nordpool system, which does account for international transfers but ignores important within-zone constraints, for instance between north and south in Sweden). In the early years of the first markets in the US (PJM and the New England markets), a market similar to the current European system resulted in increasing constraints and triggered emergencies. Chronic intrazonal transmission capacity problems have also led the other organized markets in Texas and California to abandon zonal pricing systems in favour of locational marginal pricing.

This shows that while the existing European power market design was viable for situations in which power grids were tailored to domestic markets with their base load generation plants, it requires adjustments as transmission constraints become increasingly important due to intermittent generation at new locations, and changing electricity flow patterns. It is thus increasingly important for national and international power markets to reflect actual transmission constraints.

Additionally, designs that couple markets still fail to provide for the effective co-ordination of intraday dispatch and balancing markets across the European network that is needed to facilitate the incorporation of intermittent power sources. Prior to the large-scale deployment of wind power, intraday markets were required only in response to power plant failures; balancing markets were required to respond to power plant and line failures and to correct for small errors in demand forecasts. As short-term wind forecasts improve, intraday markets gain importance, and facilitate the economic operation of the power system; hence their effective design across Europe is now of relevance.

These shortcomings and options for addressing them are discussed in more detail in two complementing papers.

In contrast, the integrated market system has the following advantages:

- Full information-sharing: The full visibility of the state of the network allows for a comprehensive security check to avoid black-outs which have often occurred where interactions across the system were not anticipated by individual TSOs due to the limited information available to them. The ISO is thus also in a position to co-ordinate responses to system failures. The current EU approach, of uncoordinated responses by individual TSOs, risks unanticipated consequences in the regions of neighbouring TSOs[4].
- Pricing reflective of transmission constraints: An integrated design managed by an ISO is a big improvement on current clearing methods under current market coupling arrangements, because the actual transmission constraints are considered, rather than the approximations currently provided by individual TSOs to power exchanges. Transmission constraints within countries and specific locations of planned generation are reflected in the market clearing process so as to create prices that signal the value of producing and cost of consuming power at different locations. This is currently not possible, because power exchanges do not have information about the state of the network, but are only informed by TSOs about the maximum volume of bilateral commercial transactions between countries.
- Incorporation of generation constraints: Day-ahead and intraday markets facilitated by an integrated power market also allow for efficient operation of the different generation assets by taking into account their start-up costs, ramping times, and part-load constraints when deciding on an efficient provision of energy and various types of system services. This has already been implemented within the joint Spanish and Portuguese power market and is standard across the locational marginal pricing regimes in the US.

In addition, because the integrated power market provides full system visibility, pricing that accurately reflects system constraints, and can provide a platform for day-ahead and intraday trading, it allows for the incorporation of intermittent energy sources. This is particularly important for less predictable sources such as wind, for which forecasts improve markedly closer to production.

Ultimately, the integrated power market increases trade and creates network efficiency as energy supply more closely matches demand. In the US, the integrated market systems have resulted in an increase of the commercial transfers across critical interfaces of 2400 MW and almost USD 200 million per year in net benefits from increased power trade[5].

Bilateral Trading is Compatible with an Integrated Power Market

Although integrated markets provide ISOs with monopoly positions, they facilitate a variety of transaction types. In the US experience, commercial power transactions are dominated by bilateral transactions among market parties and on commercial platforms separate from the ISO. Spot sales in the day-ahead and real-time markets are only a small proportion of the total traded volumes but are essential, as they create a robust reference price for many of the financial transactions. Thus, management and pricing of the full set of network constraints day-ahead is compatible with a commercial system dominated by bilateral trading. The integrated market complements, rather than replaces, bilateral trading or power exchanges.

[4] See presentation from Janusz Bialek, University of Durham, Information Sharing and System Security,
[5] See presentation by Andrew Ott, PJM, Technical Feasibility: expansion of PJM to east: (1) Prior to Integration: Transfer Capability PJM & ECAR to DVP = 2800 MW + 2750 MW; (2) After Integration: Proxy for Transfer Capability Northern & Western Market Area to DVP = 4000 MW + 3950 MW (see www.climatepolicyinitiative.org). Value of saving quantified in Mansur, E., & White, M., "Market Organization and Market Efficiency in Electricity Markets," Yale School of Management Working Paper, June 2009. http://bpp.wharton.upenn.edu/mawhite/papers/MarketOrg.pdf

5 Options for transition to an integrated power market

Integrated power markets offer many advantages that other options do not, but a transition to such a market is not without challenges. One path for European transition to an integrated power market is to create independent ISOs that would interact with national TSOs. This could ensure operation is independent from any specific company or national preference, while recruiting staff from various TSOs could ensure the level of know-how required for the operation of such an ISO. However, setting up a new institution can take time, and the pragmatic approach might thus involve a closer integration of the system operation functions of existing TSOs. This would match the experience in PJM. The local TSOs not only retain responsibility for the management and maintenance of the network, but also perform many of the operational functions using an integrated communications platform.

Another option for this transition is for existing European power exchanges to evolve into one ISO. Institutionally, this might be an attractive option, as it can build on existing organizational capacity, but it would require additional technical expertise. ISOs require significantly better understanding of the power system than power exchanges. As many power exchanges are owned by national network operators, this could serve as a starting point for a suitable ownership structure.

In practice, both of these options might have similar outcomes. European power exchanges are currently playing a dual role, conducting both short-term trading and long-term trading. With market coupling, the national power exchange that is selected to participate in the international market coupling program acquires a natural monopoly for day-ahead and intraday trading. This creates competitive advantages for longer-term trading of energy products, including existing customer access and trust, reduced transaction costs, and opportunities to balance financial exposure across various trading products. As these exchanges continue to grow both short-term and long-term capabilities, they will require increasing attention from competition authorities, leading to eventual regulation. Thus, power exchanges will either:

- Choose to specialize in short-term trading -- possibly evolving into an ISO.
- Shift their activities to longer-term trading – thus creating the space for a separate entity to act as an ISO managing short-term trading.
- Split their functions between short-term trading activities and longer-term trading activities. The short-term function could then equally turn into an ISO.

As discussed previously, these changes to power market design will not undermine bilateral energy trade or limit long-term trading. On the contrary, they can create robust reference prices that facilitate increased trading of tailored long-term products and allow for a simple transfer of existing contractual arrangements.

6 Positions of and incentives for key players in the transition to a new power market

The various actors in the European power market face different situations and considerations in transitioning to an integrated power market. Figure 4 summarizes the positions of various European actors to a transition to an integrated market.

Transmission system operators have traditionally been reluctant to engage in international co-operation. Even simple protocols on sharing information have been delayed for years. This might be attributed to:

- Vertical integration with generation and reluctance to enhance the level of European power market integration;
- Reluctance to abandon the practice of reducing possible international transactions for conservative management of transmission capacity (operators often stand to gain from creation of new transmission lines rather than using existing lines efficiently);
- Additional competition generated by a more integrated system;
- Lack of internal management systems, which would be exposed in the case of more transparency; and
- General attitude of limiting the level of information made available to regulators, in order to strengthen their own position in negotiations with regulators.

With the increasing success of vertical unbundling, however, some of the incentives to exercise market power are reduced. The past experience of power system failures shows the importance of European-wide information sharing based on clear protocols to facilitate co-ordinated operation of the system. This avoids delays on interconnection of renewables and creates incentives to enhance the utilization of the network (e.g. the U.K. experience of National Grid Transmission). Meanwhile, challenges in the planning process for new lines are likely to require more transparency on the status and utilization of the network to present a robust justification for new investments.

Conventional generation companies have for a long time benefited from dominant positions in their domestic markets, creating incentives to limit the level of international competition and the potential for entry by third parties. Thus, an inefficient power market was in their interest, as it both restrained international power flows and created risks in opaque and illiquid intraday and balancing markets for new entrants.

With incumbent utilities shifting to renewable technologies, their interest in the success of implementation and grid connection for renewable projects is increasing, potentially outweighing incentives to obstruct improvements to power market designs.

A second aspect to consider is the role of locational marginal prices, an essential component of smart power market design. Locational marginal prices are, particularly in exporting regions, lower than the average power price received by generators in the current power market design, thus, in theory, creating incentives to obstruct improvement to the power market design. The US experience shows, however, that all generators in exporting regions were compensated with financial transmission rights. The higher utilization of the network under locational marginal pricing allows for generous compensation, and as a result, generators that anticipate losing from a transition to locational marginal prices, in practice win from the transition.

Investors / renewable generation companies have in most European countries focused their effort on acquiring and maintaining priority grid access with guaranteed revenues under a feed-in tariff. While this approach was successful for limited penetration of renewable energy, it will be difficult to maintain with increasing penetration of renewable generation sources.

One option for the feed-in tariff is to shift towards a two-part tariff, comprising a payment that is received whenever the generator can produce (but does not necessarily dispatch) energy, and an additional payment to cover marginal costs (maintenance costs for wind power) in the case of dispatch. This guarantees stable revenue streams to facilitate low-cost financing while allowing effective dispatch of the system.

Support schemes that involve a premium payment, in addition to wholesale price revenues, can equally be integrated with smart power market design if financial transmission rights are allocated to investors to hedge against uncertainty of locational prices.

With increasing penetration of renewable energy sources in European power systems, an ineffective power market design would create significant constraints, resulting in delays to new investments. Hence, actors in the renewables scene are increasingly address power market design aspects in their discussions. Otherwise, uncertain future deployment opportunities could undermine business models of manufacturers and project developers.

National governments and regulators have often relied on industry expertise to inform their decisions on power system operation, and regulators have also initially focused their efforts on setting tariffs for and ensuring third-party access to the distribution and transmission networks. With the reluctance of incumbent utilities to enhance international competition or facilitate third-party entrance, only Spain (and Portugal) and the Scandinavian countries have actively pursued effective improvements to their power market design. Growing electricity demand, in combination with a ban on conventional power station investment, created an early interest among utilities in these countries in renewables investments, which propelled the advancement of market design. In Scandinavia, the interest in sharing the benefits of hydro reservoirs and pooling the uncertainty about rainfall patterns can explain the closer co-operation with other TSOs.

Concerns about delayed grid connection of new wind turbines moved congestion management and power market design up the agenda of UK policy makers, and is likely to create increasing interest across continental Europe as well.

Power exchanges are new actors that have emerged in Europe over the last 10 years. They facilitate day-ahead trading, intraday trading and provide a platform for longer-term trading. The need for liquidity has typically resulted in the concentration of all national activities in one power exchange, except in the U.K., where the strong role that brokers continue to play prevented such a concentration for a long period of time. While all power exchanges offer the opportunity to trade longer-term products, their market share and activity in these products varies across countries.

The opportunity to implement market coupling reinforces the position of power exchanges significantly. With the linking of transmission allocation to the trade on the day-ahead market, more market participants must use the national power exchanges. This in turn will also strengthen their role in trading longer-term products.

A transition to a smart power market design would significantly change this situation. The ISO as a regulated entity would host an intraday and day-ahead smart auction but would be banned from trading longer-term energy products. This creates space for power exchanges to design tailored longer-term products, but also opens the market up for competition by third parties. Thus, power exchanges that have a strong interest in advancing the agenda of market coupling might turn out to be strong opponents of further improvements of the power market design unless they anticipate playing a stronger role in such a market design.

Figure 4: Summary of likely positions of European actors on transition to an integrated power market.

European power system actor	Position
Transmission system operators (TSO)	Reluctant to engage in international cooperation, but with increased vertical unbundling, less incentivized to exercise market power.
Conventional generation companies	Traditionally benefit from inefficient power market due to the current dominant position. Increasingly interested in renewables, however, in order to stay competitive. Concerned about lower locational marginal prices, though US experience shows that revenue from financial transmission rights compensates.
Investors/renewable generation companies	Supportive of smart power market design, but concerned about loss of guaranteed revenues (where not covered by feed-in tariff regimes). Consider use of Financial Transmission Rights (FTRs) or two-part tariff to de-risk revenue stream.
National governments and regulators	Mixed: Spain, Portugal and Scandinavian countries have supported smart power markets, but others have typically focused on tariffs and third party access to networks. Delays in renewable deployment (UK), and costs/planning issues on grid expansion (Germany) create increasing interest in power market improvements.
Power exchanges	Support market coupling which reinforces their position. May be strong opponents to system that will limit their intraday activity and facilitate competition in long-term trading.

The role of European policy

The mixed positions of the various actors on smart power market design, suggests that it will only be implemented if a political institution takes a strong leadership role. National regulators are unlikely to co-ordinate such an effort because they are likely to defend the vested interests of their national champion. Hence, a European initiative is required to move the agenda forward, with the following benefits:

- Benefits of EU market integration;
- Ability to deliver renewable targets;
- Technical competence and ability to identify benefits for European consumers;
- Synergies and security of supply for European energy provision;
- Creation of environment that allows for deployment of innovative control technologies;
- Avoiding conflicts that might otherwise arise between countries on the provisions under which off-shore grids are interconnected; and
- Creation of transparent market prices to inform priorities for trans-European networks.

7 Conclusion

Economists have frequently focused their analysis of power markets on day-ahead and long-term markets. Yet like some economists' advice to deregulate financial markets, analysis restricted to a narrow view of the whole system can easily result in misleading recommendations. When considering the broader goal of transition to a low-carbon power system, an integrated power market with locational marginal pricing is superior to the existing European model and to improvements such as market coupling and the incorporation of international loop flows, because it:

- Shares information to enhance system stability;
- Provides transparent information for the monitoring of and response to market power;
- Makes efficient use of network by reducing system operation cost;
- Makes efficient use of network by reducing network expansion requirements;
- Makes efficient use of network by facilitating additional connection of renewables to the network; and
- Creates transparent price signals to inform investment choices.

Ultimately, the benefits to various actors of a transition to an integrated power market system outweigh the disadvantages. Given the likely reluctance of various actors, however, this transition will require strong European leadership.